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OPTIMALLY FUNDING ARMY INSTALLATION REPAIR AND MAINTENANCE ACTIVITIES

by

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OPTIMALLY FUNDING ARMY INSTALLATION REPAIR AND MAINTENANCE ACTIVITIES

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ABSTRACT

The Army's Assistant Chief of Staff for Installation Management (ACSIM) allocated over $4.862 Billion in 1995 to over 200 Army installations for Repair and Maintenance Activities (RPMA). However, this allocation and those of the recent past have historically covered only 40 to 70 percent of total requirements. In response, ACSIM developed an efficient and defensible management paradigm called Infrastructure Decision Architecture (IDA). The IDA contains a model called the Decision Support Tool (DST) that projects future infrastructure status given a proposed six year budget, the current infrastructure status, a funding hierarchy, and an infrastructure priority. This thesis develops a linear program incorporating the goals of the IDA into an optimization based decision support system, completing the DST. This thesis affords ACSIM decision makers the following abilities: a projection of the optimal inventory status resulting from a given budget; the six year annual allocation policy to obtain the optimal benefit; the ability to defend budget needs concerning desired infrastructure status in the procurement cycle; and the ability to conduct "what ifs" on different budget strategies and infrastructure end states. Successful model runs for eleven different Major Commands using Fiscal Year 1996 data resulted in installation infrastructure status projections and annual funding consistent with ACSIM priorities.

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EXECUTIVE SUMMARY

The Army's Assistant Chief of Staff for Installation Management (ACSIM) allocated over $4.862 Billion in 1995 to over 200 Army installations for Repair and Maintenance Activities (RPMA). However, this allocation and those of the recent past have historically covered only 40 to 70 percent of total requirements. In response, ACSIM developed an efficient and defensible management paradigm called Infrastructure Decision Architecture (IDA). The IDA contains a model called the Decision Support Tool (DST) that projects future infrastructure status given a proposed six year budget, the current infrastructure status, a funding hierarchy, and an infrastructure priority. This thesis develops a linear program incorporating the goals of the IDA into an optimization based decision support system, completing the DST. The DST created in this thesis affords ACSIM decision makers the following abilities: a projection of the optimal inventory status resulting from a given budget; the six year annual allocation policy to obtain the optimal benefit; the ability to defend budget needs concerning desired infrastructure status in the procurement cycle; and the ability to conduct "what ifs" on different budget strategies and infrastructure end states.

The model uses the current infrastructure inventory status and costing factors from an Army database, a proposed six year RPMA budget and optimizes the weighted rating of the inventory while the following constraints restrict this objective: total cost must be within annual budget limits; all inventory must maintain a mandatory level; and total inventory is neither created nor destroyed.

Model runs for eleven Major Commands resulted in the optimal funding allocation strategy and the inventory status projector ACSIM needs to efficiently manage and defend its budget.

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I. ARMY INSTALLATION REAL PROPERTY MAINTENANCE

For the United States Armed Services, the reality of the post cold war peace dividend is a 40 percent reduction in appropriations. The Army Chief of Staff for Installation Management (ACSIM) manages all Army installations, and the diminished budget is causing a change of ACSIM's management paradigm. ACSIM must allocate the $4.862 Billion annual Army installation operating budget in an efficient and defensible manner. This thesis develops a linear program to help ACSIM determine an efficient six year annual allocation. These six years correspond to a six year process known as the Program Objectives Memorandum (POM).

A. BACKGROUND

During the past few years a new strategy of power projection in response to regional conflicts evolved from the strategy of containing the spread of communism. The power projection platforms are Army installations acting as command centers, industrial plants, training facilities, ports, research labs, and home to thousands of soldiers and their families [ACSIM, 1997]. In an environment of shrinking budgets, the operation of these installations, known as Real Property Maintenance Activities (RPMA), becomes an exercise in efficient fiscal usage. At any of the over 200 installations, a diminishing budget coupled with constant demands on those dollars creates many new challenges. In 1995, RPMA cost the Army $4.862 Billion. Of this total expenditure, Operation of Utilities (J Account) consumed $1.191 Billion, the Maintenance and Repair of Real Property (K

Account) consumed $1.868 Billion, Minor Construction (L Account) consumed $243 Million, and Other Engineer Support (M Account) consumed $1.560 Billion [Department of the Army, 1996]. (Figure 1)

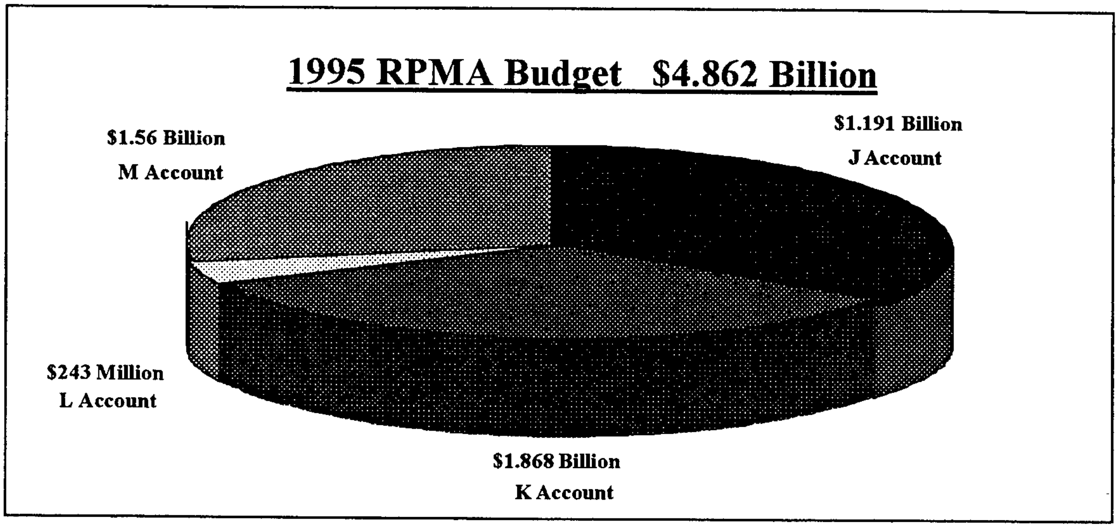

Figure 1. The Army's $4.862 Billion operating budget for Repair and Maintenance Activities is larger than the operating budget for 22 states. [ACSIM, 1997]. This thesis uses a linear program to maximize the benefit for all moneys spent in the J, K, L & M accounts.

One of ACSIM's major missions is the procurement and management of RPMA dollars. Investment in the preservation of infrastructure must compete with all the other dollar demands in the limited Army budget. The Army RPMA procurement is routinely between 40 to 70 percent of the projected RPMA requirements. This shortfall creates the dilemma of what infrastructure to invest in and what to let depreciate.

B. ACSIM

Just before the creation of ACSIM in 1993, the Army published a paper called *Installations: A Strategy for the 21st Century*. This paper outlined eight "goals and

objectives for achieving a new installation management paradigm" [ACSIM, 1997]. Since its formation, ACSIM executes its duties according to these eight goals:

- Reshape installations to meet power projection specifications.
- Formulate soldier and civilian employee programs to enhance the quality of life, and improve the living and working environment for soldiers, families and civilians.
- Achieve total integration of environmental stewardship into installation operations.
- Establish and resource an investment plan for our enduring installations to revitalize or replace installation infrastructure facilities.
- Complete installation-level business process and functional redesign to off-set the impact of down-sizing and continuing resource constraints, improve service, and reduce costs of running installations; incorporate a modernized telecommunications network to support voice, data, and image services.
- Achieve community, inter-service, and interagency partnerships for facilities and services to improve operations, customer service, and fiscal effectiveness and efficiency.
- Attain resource management flexibility for the Garrison Commander through policy, procedures, and systems changes that will enable installations to operate as business activities and maximize the effectiveness and efficiency of resources.
- Transform the Army's Human Resource programs to build a participative, committed, installation management team capable of meeting the uncertainties and technological complexities of a constantly changing environment. [ACSIM, 1997].

The fourth goal specifically illustrates the need for an efficient plan to maintain and upgrade installation resources. The current plan, still in its infancy, is called the Infrastructure Decision Architecture (IDA). The IDA links decisions to future projected conditions of the installation resources.

C. INFRASTRUCTURE DECISION ARCHITECTURE (IDA)

IDA contains the following major ideas: first, a simple method of measuring and evaluating the status of infrastructure; second, a funding hierarchy; third, a priority of infrastructure; and last, a decision support tool that incorporates the first three ideas with a budget resulting in an infrastructure status forecast for the proposed budget [Shelton, 1996]. ACSIM developed an evaluation system called the Installation Status Report (ISR) to fulfill the first part of the IDA, but has not fully completed the latter three. The linear programming model developed in this thesis incorporates the ideas of IDA into an optimization based decision support system, completing the IDA Decision Support Tool.

1. Installation Status Report (ISR)

ISR is a three part information system intended to provide decision makers an objective assessment of the status of Army installations with respect to infrastructure (ISR Part I), environment (ISR Part II), and services (ISR Part III) [ACSIM, 1997]. Only the ISR Part I (Infrastructure) is applicable to this thesis, and therefore future references to ISR refer to this section. Installations report the status of facility category groups (FCGs) each year. There are currently 217 different FCGs rated in the ISR, examples include record firing ranges, brigade headquarters buildings, and fixed wing runways. The infrastructure ISR rates FCGs in both quantitative and qualitative categories.

A "C-rating" provides the qualitative measure of each FCG. The user of an individual facility completes a standardized worksheet resulting in an facility quality rating

of green, amber or red. A loose definition of the three color ratings is as follows: green - the facility meets all operational standards; amber- the facility is operationally functional, but does not meet all standards; and red - the facility is substandard and not operationally functional. The ISR computes the qualitative C-rating by the percentage of FCG rated green, amber or red at each installation. The rating of C-1 is the highest and C-4 the lowest; C-5 is a separate rating given installations in the process of closing. Figure 2 shows the percentage breakout for qualitative C-ratings.

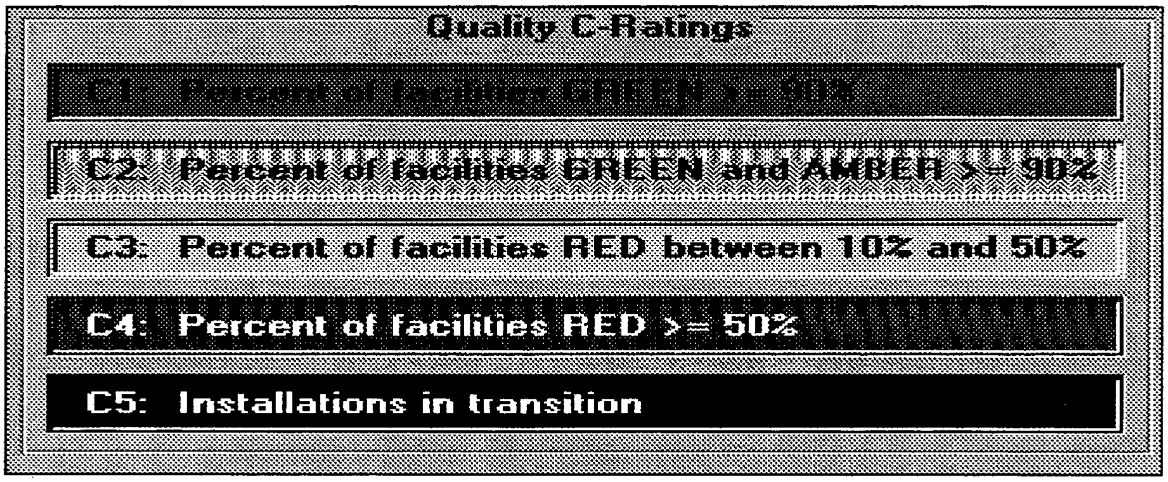

Figure 2. The infrastructure ISR rates qualitative status of infrastructure using C-ratings. The rating of C-1 is the highest and C-4 the lowest; C-5 is a separate rating given installations in the process of closing. The ISR computes the qualitative C-rating by the percentage of FCG rated green, amber or red at each installation. This C-rating is adopted from the Army's current Unit Status Report (USR).[ACSIM, 1996]

The ISR determines and can display the C-rating for each FCG at each installation; it can also display C-ratings for aggregates of FCGs (sub-categories, categories, or mission area) and aggregates of installations (major commands and Army). Figure 3 shows an ISR mapping of MACOM by Mission area.

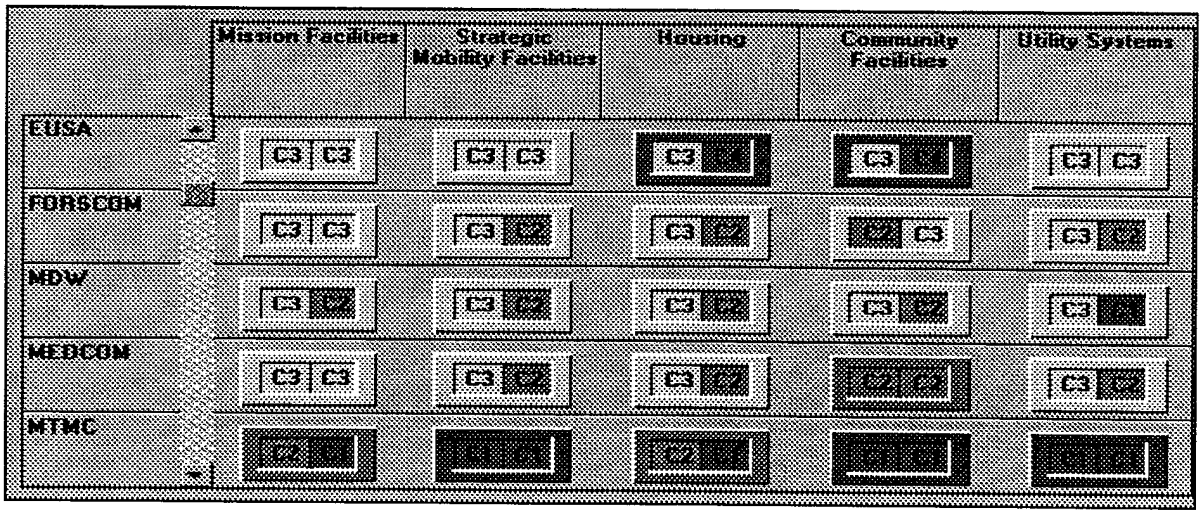

Figure 3. The ISR rolls up the green, amber, and red FCG ratings showing status as a C-Rating with a fidelity of installations and the ability to aggregate up to either MACOM or Army level. The FCGs are aggregated up to sub-category, category and mission area levels. The above rating is a mapping of mission area by MACOM[ACSIM, 1996].

The ratio of required on-hand permanent and semi-permanent FCG assets determines the quantitative rating. An example of the quantitative rating is: the Army Stationing and Installation Plan (ASIP) requires an installation to have X square feet of barracks space. That installation's Real Property Inventory (RPI) reflects Y square feet of barracks available. The ratio of $\frac{Y}{X}$ determines the quantitative C-rating. This thesis assumes that qualitative issues (improvement and sustainment of inventory) use moneys from only the J, K, L, and M accounts. It follows then that quantitative issues (construction and demolition of inventory) satisfied from other accounts are not considered in this thesis.

Included in the ISR database is the cost needed to sustain an FCG at the current rating, and the cost to raise an FCG to a higher rating. In short, this rating system

provides leaders with the current installation infrastructure status, and a forecast of dollars needed to maintain and improve the status. The Chief of Staff of the Army approved this system in July of 1994. The Army conducted a partial ISR in 1995 and a complete Army survey in 1996.

2. The Hierarchy of Infrastructure Funding Needs

Three cost categories construct the hierarchy of infrastructure funding needs: cost for minimum essential services and operations, sustainment costs, and improvement costs.

Minimum essential services and operations (MESO) are the

> "minimum health, safety, environmental, and repair services to host and tenant activities in compliance with legal requirements that require funding in the specific year. If only minimum essential services and operations are funded, the condition of the infrastructure will eventually deteriorate to the point where the installation will not be able to meet its mission requirements" [Wylie and Osgood, 1996].

ACSIM created MESO cost factors for each FCG since realizing that infrastructure requires a minimum level of funding as long as it is being used, even if it is not sustained at its current status. A general industry standard for this minimum funding is three percent of sustainment costs [R&K Engineering, 1996]. Unfortunately, the Army's data on repair and maintenance does not distinguish between what is needed for the sustainment of infrastructure and what is essential to the infrastructure. This lack of clarity injects subjectivity and skepticism into the MESO cost factors, but not the need to have them. The linear programming model developed in this thesis accounts for the minimum funding required using a MESO factor.

The sustainment and improvement cost factors used in the ISR are the same cost factors the Army uses in its current requirements generator. The sustainment cost factor is the amount of money required to keep a unit of an FCG at its current rating. The improvement cost factor is the money required to raise a unit of an FCG from either red or amber to green. Note that if a unit of FCG rated as red is improved, its rating is raised to green not the next higher rating of amber. These three cost factors create the hierarchy of funding needs of the IDA.

3. Priority of Facility Category Groups

Since the Army only appropriates about 40 to 70 percent of needed RPMA funding, it must prioritize infrastructure. ACSIM has created a priority listing for all FCGs for each of the fifteen installation mission types. The fifteen installation mission types are: administrative support, ammunition production, ammunition storage, base realignment and closure, commodity commands, depots, industrial bases, major training areas, maneuver installations, medical centers, ports, professional schools, proving grounds, reserve component support, reserve component training, and training schools. ACSIM identifies each installation as performing one mission type and prioritizes each FCG as either 1, 2, or 3 for every installation mission type. Priority 1 is the most important and 3 the least important.

D. PROBLEM DEFINITION

Installations use a capital budgeting methodology of parceling out sustainment and improvement funding to infrastructure. This allocation scheme typically under funds the minimum essential services violating the hierarchy of infrastructure. Strictly enforcing the hierarchy exhausts the RPMA funds on MESO and sustainment costs, but little or no improvement is realized. This scheme rarely allows the desired improvement in infrastructure, and is obviously flawed. A future "balanced approach" allows for all MESO costs, while allowing sustainment of some FCGs and an improvement for some percentage of the FCGs. Figure 4 graphically illustrates the three different funding methods.

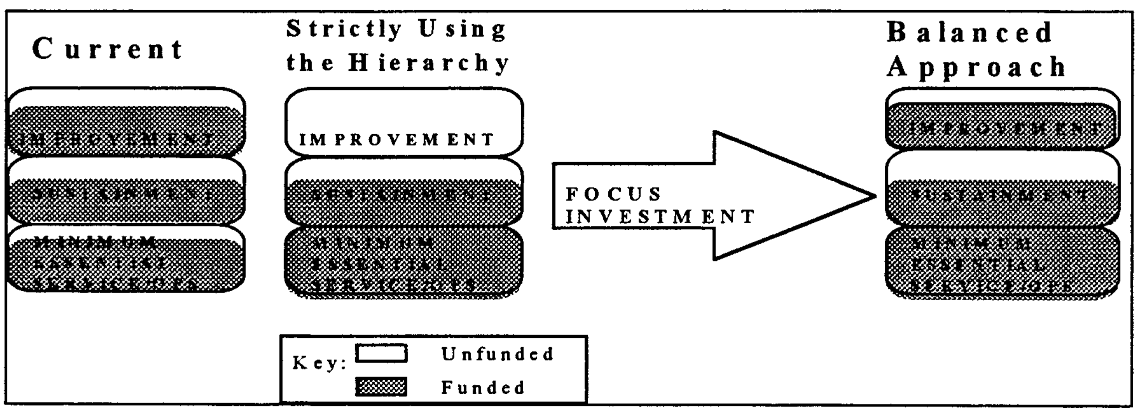

Figure 4. The methodologies for Real Property Maintenance Activities (RPMA) funding allocation. Currently, installations parcel out funding for infrastructure to each of the three categories. Funding allocation covers minimum essential and sustainment costs, but little or no improvement is paid for if the hierarchy is strictly used. A future "balanced approach" allows for all MESO costs, but some of the FCGs are sustained and some improved.[Shelton, 1996]

The purpose of the IDA is to provide information and decision support for determining which FCGs to sustain, which to let depreciate, and which to improve. The

linear programming model developed in this thesis fulfills the IDA's purpose and affords ACSIM:

- a "best case" of future status resulting from a proposed six year annual budget;
- the ability to formulate an allocation policy for RPMA to obtain the maximum benefit;
- the ability to defend budget requirements concerning desired infrastructure status in the procurement cycle; and
- the ability to conduct "what ifs" on different budget strategies and infrastructure end states.

E. THESIS ORGANIZATION

This thesis provides a linear programming model that maximizes benefit for each dollar spent in repair and maintenance (J, K, L and M Accounts) while adhering to budget, MESO, and inventory constraints.

Chapter II reviews work related to this model. Chapter III provides the model formulation and defines the weights used in the objective function. Chapter IV reports the execution of the model using the 1996 ISR data. Chapter IV also analyses the output of that model run for several MACOMs. Chapter V provides conclusions and recommends future work.

II. LITERATURE REVIEW

A. CAPITAL BUDGETING

Many Capital Budgeting problems such as the one described in Chapter I have been documented in the operations research literature. Past models normally maximize the net present value of assets subject to a funding stream or budgetary constraint. Bradley [1986] illustrates the benefits of mathematical programming within a decision support system designed to manage the capital investments of GTE. Bradley's integer linear program enables decision makers to quickly evaluate the investment alternatives in a given time horizon by maximizing the net present value of the portfolio. Rosenblatt and Sinuany-Stern [1989] develop an integer program defining the efficient frontier for a capital budgeting problem using two objective functions. One objective function maximizes the net present value of a set of "projects", the second minimizes the risk associated with each project. Carr [1996] develops a mixed integer linear programming model to select an optimal procurement strategy for missile defense systems. Carr allows the budget constraints to be violated by paying a per unit penalty related to the net present value of money. Goodhart [1997] develops a multi-objective, infinite horizon linear program to determine multi-year maintenance and repair funding levels consistent with Naval readiness objectives. Goodhart allows violation of the budget constraint through a parameter correlated to the decision maker's willingness to borrow money for the reduction of long term net costs.

The model developed in this thesis uses a budget constraint similar to Carr and Goodhart, and a weighting to combine the multiple net present values of the different facility category groups into one objective function, similar to Rosenblatt and Stern. The resulting model allows decision makers at ACSIM the ability to evaluate different allocation strategies in a timely manner. The remainder of this Chapter reviews several models created to fulfill the requirements of the Army's IDA support tool.

B. MODELING THE DECISION SUPPORT TOOL OF IDA

R&K Engineering [1996], under contract from ACSIM, developed the Facility Degradation Module to "predict the effect of funding increases and decreases on the condition of FCGs at the installation, MACOM, and Army-wide organizational levels". The US Army Concepts Analysis Agency [1996] developed the Yearly Analysis of Technology for Installation Readiness (YATIRP) as an analytic methodology to prioritize and evaluate investments in infrastructure. Lastly, Lind [1995] developed a model for goal oriented multiple criteria decision making that maximizes a decision maker's goals for repair and maintenance projects .

1. Facility Degradation Module

The Facility Degradation Module (FDM) computes the rate of deterioration or improvement of individual FCGs. The user inputs the ISR's current inventory status of all FCGs, the sustainment and improvement costs, and a funding allocation for each individual FCG. The FDM computes the FCG degradation/improvement rates with two

different algorithms. The first algorithm calculates the degradation rate as the ratio of annual recurring maintenance costs to annual sustainment costs. FCGs without annual recurring maintenance cost factors are assumed to have an industry standard 3% degradation rate. The second algorithm compares 1996 ISR survey results with 1995 results for facilities that were inspected in both years. Renovation costs, sustainment costs for 1995, sustainment cost factors, and the actual expenditures for 1995 are inputs for a degradation rate equation of the form:

$$\mathrm{R} = \frac{C_{96} - C_{95} + S - F}{C_{95}},$$

where C_{9x} is the renovation costs for that year, S is the total sustainment cost and F is the actual total expenditures for 1995. The degradation rate (R) is computed for each FCG for both overseas installations and continental US installations. The average of both methods provides the overall rate of change, increase/decrease, of infrastructure over time.[R&K Engineering, 1996]

The FDM does not meet all the needs of the Decision Support Tool for the IDA, since it requires annual funding allocations for each FCG and has no method to generate them. The FDM is created as an infrastructure condition projector of the IDA, not as the DST.

2. YATIRP

YATIRP is a spreadsheet based optimization model designed to deliver an allocation methodology that arrives at a fixed end state in the shortest time, while

maintaining budgetary constraints. The model user inputs the desired end state C-rating for each FCG, and the annual amount of funding and/or the funding time frame to achieve the investment goal. The model maximizes the annual gain in benefit while maintaining budgetary constraints. The benefit scores in the model are a mapping of C-ratings to score. A C-1 is scored as a six, a C-2 scored as a five, a C-3 scored as a three, and a C-4 is zero. The benefit gain is the difference between the C-1 score and the current rating [US Army Concepts Analysis Agency, 1996].

This model does not incorporate a direct sustainment cost, rather the sustainment cost is rolled into the improvement cost. The model ignores any depreciation of unsustained inventory, and inventory may be totally unfunded with no penalty. Since the objective function is calculated from the change in C- ratings, and the definition of C-1 is 90% or more of all FCGs must be green, YATIRP's optimal solution should always leave 10% of the inventory in a status other than green. YATIRP's time horizon is routinely over seven years because it takes longer to accomplish the decision maker's C-rating goals. ACSIM's ability to accurately forecast RPMA budgets for these long time lines is limited. Although a step in the right direction the YATIRP does not meet the requirements of the Decision Support Tool of the IDA.

3. Goal Oriented Multiple Criteria Decision Making

While not an attempt to model the IDA's decision support tool, Lind's thesis develops a goal oriented infrastructure management process for the US Army to aid decision makers in the allocation of infrastructure funding at the installation, MACOM and

Department of the Army levels [Lind, 1995]. This model requires surveys identifying the management goal of commanders from the installation level up to and including ACSIM. A budget decision is implemented following a complex logic scheme. Some of the assumptions of this scheme are that project budgeting is only considered for one year, projects cannot be partially funded, and projects with a higher dollar requirement for sustainment or renovation are of higher importance. The latter assumption injects weak logic into the model. A higher sustainment cost producing a higher importance of the FCG causes FCGs like golf courses to rank above rifle ranges. While this model could be an excellent tool for the installation level, the complexity and certain logic used causes this model to fail to meet the requirements of the IDA decision support tool.

III. MODELING APPROACH

This chapter presents a linear program to determine an optimal allocation, and projected inventory status for Army Repair and Maintenance Activities (RPMA). The model uses the infrastructure inventory status, and costing factors generated from the current ISR, and a proposed budget for each MACOM generated from the POM. The model optimizes the weighted rating of the inventory while the following constraints restrict this objective:

- total cost must be within yearly budget limits;
- all FCGs must maintain a mandatory sustainment level; and
- the inventory of FCGs is maintained (none is created nor destroyed).

A. MODEL ASSUMPTIONS

The model uses the following simplifying assumptions:

- MACOMs allocate RPMA moneys from the pooled total of the J, K, L , and M accounts. This model treats the total of the J, K, L, and M accounts as one RPMA appropriation. The model pays for all changes in infrastructure quality from this total.
- Money allocated for one MACOM's RPMA may not migrate to another MACOM.
- The inventory of infrastructure is continuous. A Central Wash Facility's unit of measure is "each". Spending 50% of the required sustainment cost results in half of the central wash facility being sustained, and a percentage of the unsustained inventory depreciates to the next lower rating. The same logic applies to the improvement of inventory. An allocation of a

fraction of the central wash facility improvement cost results in the same fraction of inventory improved.

B. THE MODEL FORMULATION

This section defines the sets, indices, data, variables and the mathematical formulation of the model.

1. Model Sets and Indices

- **f** Facility Category Group (FCG) {e.g., impact areas, indoor firing ranges, bank}. ACSIM has defined 217 FCGs with units of measure ranging from acres to square yards to firing points. The model uses a six digit alphanumeric identifier for each FCG.

- **i** Installations - the names of all the Army installations {e.g., Carson, Benning} The model uses the five digit alphanumeric Installation Number (INSO).

- **m** MACOM name of major command {e.g., Military District-Washington, AMC }.

- **p** Mission type - primary mission of the installation {e.g., training, maneuver} ACSIM has defined fifteen different installation mission types.

- **r** Rating - the rating of infrastructure as defined in the ISR {green , amber, red}.

- **t** Time - year of the budget planning cycle {1,2,3,4,5,6,7} Years one through six are the six years of the POM, year seven is the model's end state after six years of spending.

- $\mathbf{I_m}$ the set of all installations belonging to MACOM (m).

- I_p the set of all installations having mission type (p).

2. Data

- **wght** $_{f, i, r, t}$ The benefit for a unit of an FCG (f), on installation (i), of category rating (r), for year (t). units = [benefit/unit of FCG] .

- **scaledata** $_f$ The scalar for each FCG used to create parity in the objective function among the heterogeneous set of FCGs.

- **pen** $_t$ The penalty for exceeding the annual budget by one dollar in year (t). units = [-benefit/Then Year$].

- **scost** $_{f, i, r, t}$ The cost to sustain one unit of FCG (f), on installation (i), at rating (r), in year (t). Money spent in year (t) maintains a rating (r) in year (t+1). units = [Then Year$/unit of FCG].

- **cost** $_{f, i, r, t}$ The cost to raise a unit of FCG (f) , on installation (i), from rating (r) to green, during year (t). The money spent to upgrade in year (t) results in a green rating in year (t+1); The cost to raise one unit of FCG is in addition to the cost to sustain the same unit of FCG in year (t). units =[Then Year$/unit of FCG].

- **budget** $_{m, t}$ The budget for repair and maintenance (J, K, L & M accounts) allocated to MACOM (m) in year (t). units = [Then Year$].

- **minesen** $_{f, i, t,}$ The funding required for an FCG (f) on installation (i), in year (t). units = [Then Year$/unit of FCG].

- **perclossf, i, t** The percentage of non-sustained inventory of FCG (f), at installation (i), that depreciates from rating (r) to (r+1) in year (t). Inventory not sustained degrades to rating (r+1) in one year at a rate equal to non-sustained inventory times percloss.

- **value$_{f,\,p}$** the priority given an FCG for each mission type p. The priority is either one, two, or three. This data is used in the calculation of the weighting benefit wght parameter.

3. Model Decision Variables

- **INV** $_{f,\,i,\,r,\,t}$ the amount of inventory of FCG (f) on installation (i), in rating (r), at beginning of year (t). The level of inventory at the beginning of year one (t=1) is data.

- **CINV** $_{f,\,i,\,r,\,t}$ the inventory of FCG (f) on installation (i), increased from rating (r) to rating green, during year (t); the green rating is realized in beginning of year (t+1).

- **SUS**$_{f,\,i,\,r,\,t}$ the inventory of FCG (f), on installation (i) sustained with funding in year (t). The inventory sustained maintains an (r) rating into year (t+1), the inventory not sustained depreciates at a rate equal to the amount of unsustained inventory multiplied by percloss$_{f,\,i,\,t}$.

- **OB** $_{m,\,t}$ the dollars spent on repair and maintenance over the allocated annual budget for MACOM (m) in year (t).

4. Formulation (Separable by MACOM (m))

objective function

Equation(1) $$\text{Maximize} \sum_{f,\,i,\,r,\,t>1,} \text{wght}_{f,i,r,t}\,\mathbf{INV}_{f,\,i,\,r,\,t} - \sum_{m,t>1} \text{pen}_t\,\mathbf{OB}_{m,t}$$

budget constraint

Equation(2): $$\sum_{f,\,i\in Im,\,r} \text{scost}_{f,\,i,\,r,\,t}\left(\frac{\mathbf{SUS}_{f,\,i,\,r,\,t}}{\text{percloss}_{f,\,i,\,t}}\right) + \sum_{f,\,i\in Im,\,r\neq green} \text{cost}_{f,\,i,\,r,\,t}\,\mathbf{CINV}_{f,\,i,\,r,\,t} + \mathbf{OB}_{m,t-1}$$

$$\leq \text{budget}_{m,\,t} + \mathbf{OB}_{m,t} \qquad \forall m,\ t<7$$

sustainment variable constraint

Equation(3): $$\mathbf{SUS}_{f,\,i,\,r,\,t} \leq \text{percloss}_{f,\,i,\,t}\,\mathbf{INV}_{f,\,i,\,r,\,t} \qquad \forall\ f,\ i,\ t<7$$

mandatory sustainment

Equation(4): $$\sum_{r} \mathbf{SUS}_{f,\,i,\,r,\,t} \geq \text{minesen}_{f,\,i,\,t} * \text{percloss}_{f,\,i,\,t} \qquad \forall\ f,\ i,\ t<7$$

inventory balance constraints

Equation(5): $$\mathbf{INV}_{f,\,i,r=green,\,t} = \mathbf{INV}_{f,\,i,r=green,\,t-1}\,(1-\text{percloss}_{f,\,i,\,t-1}) + \mathbf{SUS}_{f,\,i,r=green,\,t-1}$$

$$+ \sum_{r\neq green} \mathbf{CINV}_{f,\,i,\,r,\,t-1} \qquad \forall\ f,\ i,t>1$$

Equation(6): $$\mathbf{INV}_{f,i,r=amber,t}=\mathbf{INV}_{f,i,r=amber,t-1}(1-\text{percloss}_{f,\,i,\,t-1}) + \mathbf{SUS}_{f,i,r=amber,t-1} +$$

$$\text{percloss}_{f,\,i,\,t-1}\,\mathbf{INV}_{f,\,i,\,r=green,\,t-1} - \mathbf{SUS}_{f,i,r=green,t-1} - \mathbf{CINV}_{f,\,i,r=amber,\,t-1} \qquad \forall\ f,\ i,\ t>1$$

Equation(7): $$\mathbf{INV}_{f,\,i,r=red,\,t} = \mathbf{INV}_{f,\,i,r=red,\,t-1} + \text{percloss}_{f,\,i,\,t-1}\,\mathbf{INV}_{f,\,i,r=amber,t-1} - \mathbf{SUS}_{f,i,r=amber,t-1}$$

$$- \mathbf{CINV}_{f,\,i,\,r=red,\,t-1} \qquad \forall\ f,\ i,\ t>1$$

$$\mathbf{INV}_{f,\,i,\,r,\,t}\ ;\ \mathbf{SUS}_{f,\,i,\,r,\,t}\ ;\ \mathbf{CINV}_{f,\,i,\,r,\,t}\,;\,\mathbf{OB}_t\ \geq 0$$

a. The Objective Function

The objective function, Equation(1), ensures the limited dollars available are spent on the most beneficial FCGs for all installation types each year. If more dollars are spent than budgeted, the objective function is penalized for going over budget. The units of the objective function are benefit.

b. Budget Constraint

The dollars allocated to sustain inventory at rating (r) plus the amount allocated to raise inventory from (r) to green must be less than total amount budgeted for each MACOM every year. The variable $\mathbf{OB}_{m,\,t}$ allows violation of this constraint by paying a per unit penalty of pen_t.

c. Sustainment Variable Constraint

Equation (3) ensures the sustainment variable is less than or equal to the inventory of the FCG multiplied by the percent of depreciation of unsustained inventory, $percloss_{f,i,t}$. The model restricts the sustainment variable to control inventory in the inventory balance constraints (5, 6, 7). For example, if an FCG's inventory is 100 units, and the percloss parameter is 3%, then the sustainment variable is constrained to 3 units or less. The amount of inventory sustained is the sustainment variable divided by the percent loss parameter.

d. Mandatory Sustainment Constraint

Equation (4) ensures that a minimum amount of all FCGs are sustained.

e. Inventory Balance Constraints

Equations (5, 6, 7) conserve the inventory of FCG (f), at installation (i). These equations account for the change in inventory status caused by improvement, sustainment, and depreciation, while ensuring no inventory is created or destroyed at any installation.

C. BENEFIT WEIGHTING

The weights, $wght_{f,i,r,t}$ dictate how the linear program prioritizes spending. ACSIM, in conjunction with the MACOMs, ranked each of the 217 FCGs "1", most important, to "3" least important, based on the mission types. For example the FCG "Family Housing" has a ranking of "1" for installations with a training mission, a ranking of "2" for installations with a proving grounds mission, and a ranking of "3" for installations with a professional schools mission. The $value_{f,p}$ parameter captures this ranking. A mapping of the $value_{f,p}$ parameter (f by p) with the set of installations having mission type (i by p) creates the value of an FCG to a installation (f by i). The parameter $value_{f,i}$ helps create weight for FCG (f) at installation (i) in rating status "green" in year 1 using the formula:

$$wght_{f,i,r=green,\,t=1} = \frac{1}{value_{f,i}}.$$

The formula:

$$wght_{f,i,r,t=1} = (wght_{f,i,r=green,t=1})^{*}.8^{\text{ordinal of r}}$$

calculates weight in the dimension of (r). The ordinal of r is one for green, two for amber, and three for red. The resulting benefit weights and the respective gain in benefit for improvement from a lower status to green is illustrated for year 1 in Table 1.

Weights				Gain	
Priority	Green	Amber	Red	Amber-Green	Red - Green
1	1.000	0.640	0.512	0.360	0.488
2	0.500	0.320	0.256	0.180	0.244
3	0.333	0.213	0.171	0.120	0.163

Table 1. The benefit weight for all FCGs in year 1. The gain columns illustrate the gain in the objective function for each unit of FCG improved from amber to green and from red to green.

The gain in benefit for improving priority 1 FCGs is larger than the gain from priority 2 and the gain from improving priority 2 FCGs is larger than priority 3 FCGs. This logic creates the desired allocation methodology of sustaining and improving priority 1 FCGs before priority 2 FCGs and sustaining and improving priority 2 FCGs before priority 3.

The weighting parameter is depreciated over the seven year time horizon using the formula:

$$wght_{f,i,r,t} = wght_{f,i,r,t-1} * \left(\frac{\text{Cardinality of (t)} - (\text{ordinal of (t)} - 1)}{\text{Cardinality of (t)}} \right).$$

This depreciation ensures the model increases the most important FCGs in the earliest year possible.

1. Weighting of FCGs with respect to Units

The above weighting scheme guarantees parity among FCG of like rating and priority only if the FCGs are a homogeneous set. However, the set of units is very heterogeneous, for example 'each', firing points, square yards, miles, millions of British thermal units are some of the many FCG units. Of the 217 FCGs there are seventeen different units of measure. The units create a weighting by the difference in magnitude between them. For example, the FCG surfaced roads has units of square yards. The model pays \$14.74 to improve a square yard from amber to red. The majority of installations have hundreds of thousands of square yard of surfaced roads. For the purpose of this example we say installation (i) has 100,000 square yards of inventory. The FCG multi-purpose range complex (mprc) has a unit of measure of 'each'. The model pays \$1,491,507.73 to improve each complex from amber to red. There is only one mprc on the example installation (i). Both of these FCGs are ranked priority 1 for an installation with a maneuver mission. If the model had \$1,491,507.73 budgeted and only these two FCGs to consider, the model would gain a total of 36,000 units of benefit from improving all 100,000 square yards of surfaced roads and only 0.36 unit from improving the one mprc from amber to green. The surfaced road's numbers of inventory, and its much cheaper improvement cost, implicitly increase its weight over an mprc by 100,000 times, even though both FCGs have the same calculated weight. The parameter $scaledata_f$ dampens the extreme differences by dividing into the calculated weight parameter. This calculation manipulates the inventory numbers to be in the hundreds. In the above

example the weight for surfaced roads is divided by a scaledata value of 1,000 and the mprc weight is divided by a scaledata value of 0.01 thereby artificially changing the gained benefit to 36 units for both FCGs.

D. PENALTY WEIGHTS

The penalty in the objective function allows violation of the budget constraint which keeps the model feasible during "what if" analysis. For example, fixing the FCG Family Housing at 100% green by the seventh year, while only paying the mandatory sustainment on all other FCGs may require more money than budgeted in the POM. The elastic constraint can determine "How much more money is needed to execute the 100% green Family Housing scenario".

The penalty weights act as a "toggle" switch for the model, turning on or off the over budget variable, $\mathbf{OB}_t$. If the weight of the penalty is greater than the gain in benefit for improving inventory status, the model will only create a positive over budget variable to maintain feasibility. If the gain in benefit is greater than the penalty incurred, the model "borrows" money via the over budget variable. The standard model set up for this penalty is as follows: the standard penalty parameter pen_t is fixed at 0.1; and the model requires repayment of the $\mathbf{OB}_t$ variable by the end of POM cycle. These two settings ensure no money is borrowed unless the proposed budget is not large enough to maintain feasibility. The exploration of "what ifs", concerning how much more money is required to accomplish a set task, requires a relaxation of the payment of the $\mathbf{OB}_t$ variable, and a decrease in the penalty.

IV. COMPUTATIONAL RESULTS

This chapter presents an implementation of the DST formulated in Chapter III for eleven MACOMs. The linear program uses inventory data from the first ISR conducted in 1996, and budget data from the 98-03 POM. R&K Engineering, Inc. provided the ISR data on a Microsoft Excel spreadsheet format. The model, coded in General Algebraic Modeling (GAMS) [Brooke, Kendrick, Meeraus, 1992], uses a manipulated form of this data as input.

A. STATISTICS FROM MACOM MODEL RUNS

The eleven model runs executed for the MACOMs with complete data are as follows: Army Material Command (AMC), Forces Command (FORSCOM), Military District Washington (MDW), Medical Command (MEDCOM), Military Traffic Command (MTMC), Training and Doctrine Command (TRADOC), US Army Corps of Engineers (USACE), US Army Reserve Command (USARC), US Army Europe (USAREUR), US Army Pacific (USARPAC), and the US Military Academy (USMA). The three MACOMs without complete data are the National Guard, Eighth US Army, and US Southern Command. The initial look ISR cataloged the inventory status of only 189 installations. Many National Guard installations did not participate in this ISR. Many Eighth US Army installations double reported FCGs, corrupting its data set. US Southern Command is transitioning from installations in Central America, and did not participate in the 96 ISR.

Model runs come from either an IBM compatible PC with a 486DX4100 processor with 16 Megabytes of Random Access Memory, or an IBM RS/6000 Model 590 workstation. Table 2 lists the computational statistics from running the models using the OSL solver [Wilson and Rudin, 1992]. The average MACOM size is 11.18 installations.

MACOM	Number of Installations	Computer Used	Number of Constraints	Number of Variables	Generation Time (CPU SEC)	Execution Time (CPU SEC)	Solve Time (SEC)
AMC	22	RS/6000	66,283	89,953	45.98	57.45	4,799.00
FORSCOM	19	RS/6000	71,869	97,534	48.17	59.38	6,398.00
MDW	5	486	14,497	19,672	23.30	29.10	1,060.00
MEDCOM	3	486	10,381	14,086	15.30	19.70	706.00
MTMC	1	486	1,687	2,287	2.36	3.29	14.51
TRADOC	16	RS/6000	63,973	86,818	42.82	52.68	4,954.00
USACE	1	486	805	1,090	1.16	2.13	4.39
USARC	14	RS/6000	22,267	30,217	13.82	19.25	385.72
USAREUR	36	RS/6000	108,619	131,893	70.77	89.46	19,462.00
USARPAC	8	RS/6000	26,005	35,290	15.55	19.78	708.73
USMA	1	486	4,039	5,479	5.55	7.47	75.63

Table 2. The computational statistics of the eleven MACOM runs. Model runs come from either an IBM compatible PC with a 486DX4100 processor with 16 Megabytes of RAM, or an IBM RS/6000 Model 590 workstation. Solution time ranges from 4.39 seconds to 5 hours 24 minutes.

Upon finding an optimal solution, the model creates three comma delimited files for the results. The files are the status of inventory of all FCGs for all seven years, the funding required for improving inventory to green for the six years of the POM, and the funding for inventory sustained for these six years. The comma delimited files allow use of spreadsheets to store, analyze, and graph the results.

B. DATA

1. Indices

The indices control the dimensionality of the parameters and variables. The FCGs (f), rating (r), and time (t) are all unchanged for each of the MACOM runs. The installations (i) vary by MACOM.

a. Facility Category Group (f)

The model uses the six digit alpha-numeric FCG code to catalog the 217 different FCGs. The set of FCGs has 17 different units of measure. Table 3 shows a small subset of the FCGs.

FCG Codes	FCG Name	UM
F17893	Squad Defense Ranges	FP
F17894	Infantry Battle Courses	FP
F17898	MOUT Assault Courses	EA
F17921	Demolition/Flame Ranges	EA
F17977	Engineer Qualification Range	EA
F17995	MOUT Facilities (Non-Live Fire)	SF

Table 3. A small subset of the 217 FCG codes. The model uses the six digit FCG Code to control the dimension of the parameters and variables. These codes remain unchanged for each MACOM model run.

b. Installations (i)

The model uses the five digit alpha-numeric installation number (INSO) to catalog the 189 different installations which participated in the initial 1996 ISR. Table 4

shows a subset of the installations belonging to the MACOM Forces Command (FORSCOM).

INSO	Installation Name
42624	Charles E Kelly Support Facility
37099	Fort Bragg
RQ137	Fort Buchanan
21128	Fort Campbell
08135	Fort Carson
34201	Fort Dix
36216	Fort Drum

Table 4. A subset of the 19 FORSCOM installations. The model uses the five digit INSO code to control the (i) dimension of variables and parameters.

c. *Rating (r)*

The data set for rating has three elements {GRN, ABR, RED} indicating the inventory status of green, amber or red.

d. *Time (t)*

The data set for time is the integers {1, 2, 3, 4, 5, 6, 7}. The first six elements map onto the six years of budgeting data from the POM cycle. The last element, 7, is used as an end state allowing realization of the changes in inventory from the sixth year of budget.

2. Cost to Improve and Sustain FCGs ($cost_{f,i,r,t}$ and $scost_{f,i,r,t}$)

The Army Cost and Economic Analysis Center (CEAC) developed improvement and sustainment cost factors for each FCG expressed in dollars per unit of FCG. The sustainment cost factors indicate costs required to maintain a facility to US Army

standards and include cyclic/routine maintenance and major component replacement [Wylie and Osgood, 1996]. The sustainment cost factor is an aggregate of historical FCG maintenance expenditures for all installations in the continental United States. The four dimensional $scost_{f,i,r,t}$ parameter is equated to the one dimensional CEAC sustainment cost factor. The $scost_{f,i,r,t}$ is inflated over the time horizon using the equation:

$$scost_{f,i,r,t+1} = scost_{f,i,r,t} * (1 + \text{inflationrate}).$$

For this model the inflation rate for all costs is assumed to 7% annually.

The improvement parameters $cost_{f,i,r,t}$ are inflated in the same manner, however, CEAC derived the improvement cost factors in a different manner. CEAC first developed new construction cost factors. CEAC's new construction cost factor algorithm uses an 'unadjusted empirical unit cost for a specific FCG times an inflation factor times the technological adjustment factor times a cost data reliability factor times a contingency factor (recognizing that all construction requirements cannot be foreseen) times a supervision and administrative factor times a support facility factor and where appropriate times a demolition factor'[Wylie and Osgood, 1996]. The improvement cost factors are expressed as a percentage of new construction costs required to correct red and amber facility conditions. In general 75% of the new construction costs are used for improvement of red inventory, and 25% of the new construction costs are used for improvement of amber inventory. The model reads the cost data in from two space delimited text files.

3. Minimum Percent of FCGs Sustained $minesen_{f,i,t}$

The MESO factors described in Chapter I are not used for the $minesen_{f,i,t}$ parameter, rather the industry standard 3% of the sustainment cost is used for the model. The MESO factors ACSIM developed are still being verified. Future model runs should use the finalized MESO factors as the $minesen_{f,i,t}$ parameter.

4. Percentage of Unsustained Inventory Depreciated to Lower Status

The $percloss_{f,i,t}$ parameter is derived from the industry standard 3% annual depreciation of infrastructure. The model uses 3% as the base value for the parameters and adjusts according to specific usage of the FCG. For example the Family Housing FCG $percloss_{f,i,t}$ is set at 5% because the high usage. The $percloss_{f,i,t}$ parameters were calculated from subjective reasoning and experience of this modeler. The values range from 2 to 5 percent. The data in this file can easily be changed.

5. Starting Inventory

The data used for the beginning inventory is the status of inventory from the initial 1996 ISR survey. R&K Engineering provided this data in the form of Microsoft Excel spreadsheets. The data from the ISR is in the dimensions of FCG, installation, and rating. The four dimensional inventory variable $INV_{f,i,r,t=1}$ is fixed equal to the starting inventory data.

6. Data Scaling

The scaling parameter discussed in Chapter III provides parity among FCGs of the same priority.

7. Budget

The budget is the sum of money form the J, K, L, and M accounts as prescribed by the 98-03 POM. These sums are in ‘then year” dollars. Table 5 lists the POM 98-03 RPMA appropriation requests in thousands of “then year” dollars.

	1998	1999	2000	2001	2002	2003
AMC	153,579	131,248	155,724	171,119	156,922	174,041
FORSCOM	517,273	594,385	588,601	597,480	652,610	665,340
MDW	117,375	102,820	100,450	107,500	107,660	130,267
MEDCOM	29,033	25,503	26,322	26,472	26,880	29,971
MTMC	29,705	19,038	4,269	4,491	4,590	4,656
TRADOC	490,612	426,550	521,073	406,457	491,500	564,746
USACE	10,629	5,252	5,417	5,576	5,596	5,616
USARC	153,579	131,248	155,724	171,119	156,922	174,041
USAREUR	365,724	341,239	359,881	370,597	401,444	469,825
USARPAC	203,744	162,970	168,403	175,128	194,446	203,857
USMA	56,218	61,011	53,647	55,500	65,360	59,130

Table 5. The total of the J, K, L and M Accounts. This model assumes the allocated money can be used for any RPMA expenditure. The above sums are in then year thousands of dollars.

C. RESULTS FROM MACOM MODEL RUNS

1. Inventory Results

The obvious question a decision maker asks is 'What do I gain from this model?". One immediate answer to this question is the ability to project the status of infrastructure out seven years. This projection allows the decision maker to see the high priority inventory migrate to green. It also shows the decision maker how much, if any, the lower priority inventory depreciates. The following illustration shows the migration of square yards of fixed wing runway for TRADOC installations. Figure 5 shows the increase in green inventory for Fort Benning-13077, Fort Bliss-48083, Fort Eustis-51281, Fort Knox-21478, Fort Leavenworth-20491, Fort Leonard Wood-29977, Fort Monroe-51585, Fort Rucker-01767, and Fort Sill-40801. Eight of the ten listed installations have training missions, Fort Leavenworth is a professional school and Fort Monroe is an administrative installation. The training installations rank Fixed Wing Runways as priority 1, while Fort Monroe's administrative mission ranks this FCG as priority 2, and Fort Leavenworth's professional school mission ranks this FCG a priority 3. The X axis labeled status.year uses a two tupple combining rating and year. GRN.1 indicates the green inventory in year 1. Figures 6 and 7 show the migration of inventory out of lower status.

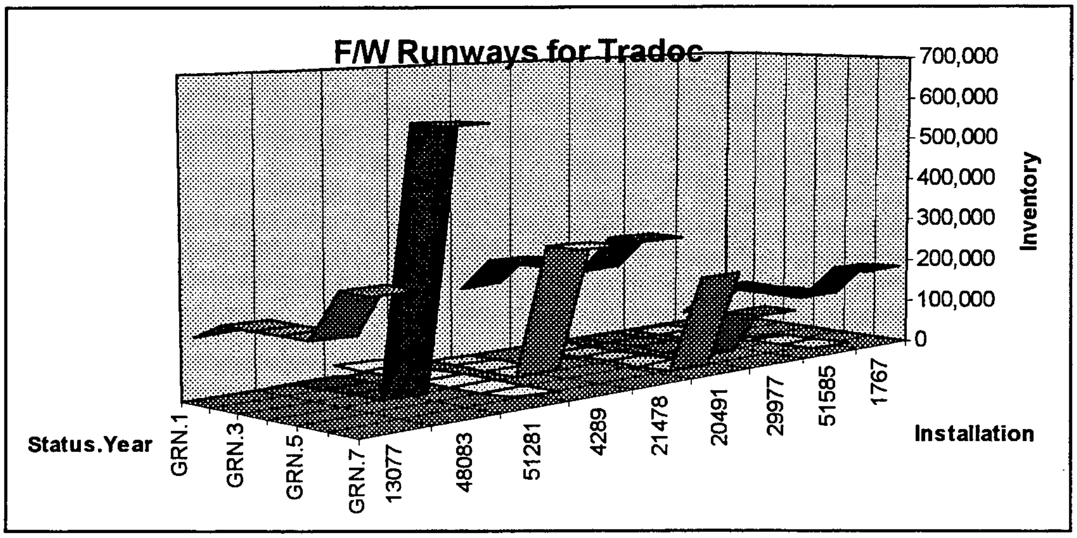

Figure 5. The migration of fixed wing runway inventory to a green status in TRADOC installations. This graph gives the decision maker the ability to visualize the gain realized by each installation in TRADOC with an inventory of fixed wing runways. The crossed hash marks in each of the inventory ribbons indicate the year of the modeling horizon. This allows the decision maker to quickly see in which year the improvement is made.

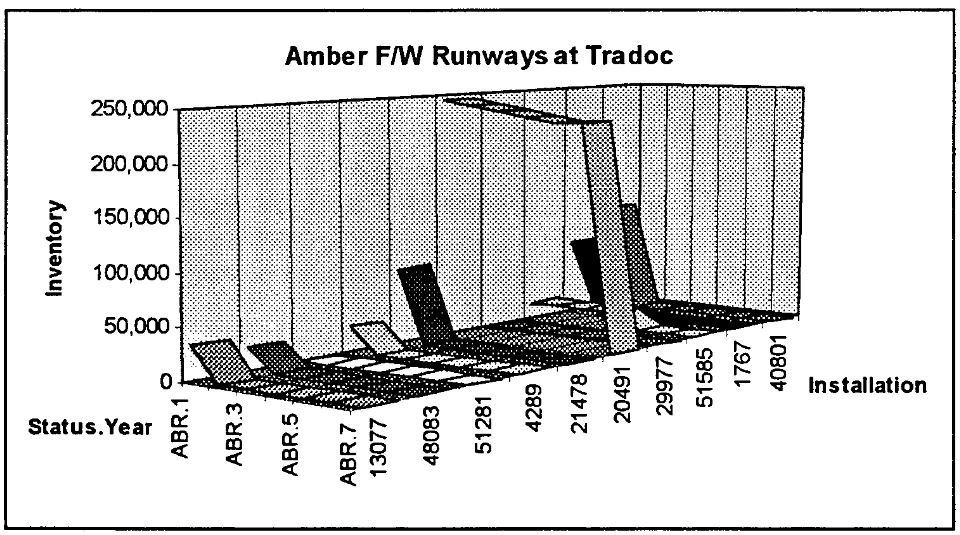

Figure 6. The migration of inventory out of the lower amber status. The decision maker can see during the first year the model improved fixed wing runways at priority 1 installations, the third year improved the inventory with priority 2 and in the sixth year the priority 3 ranking is finally improved.

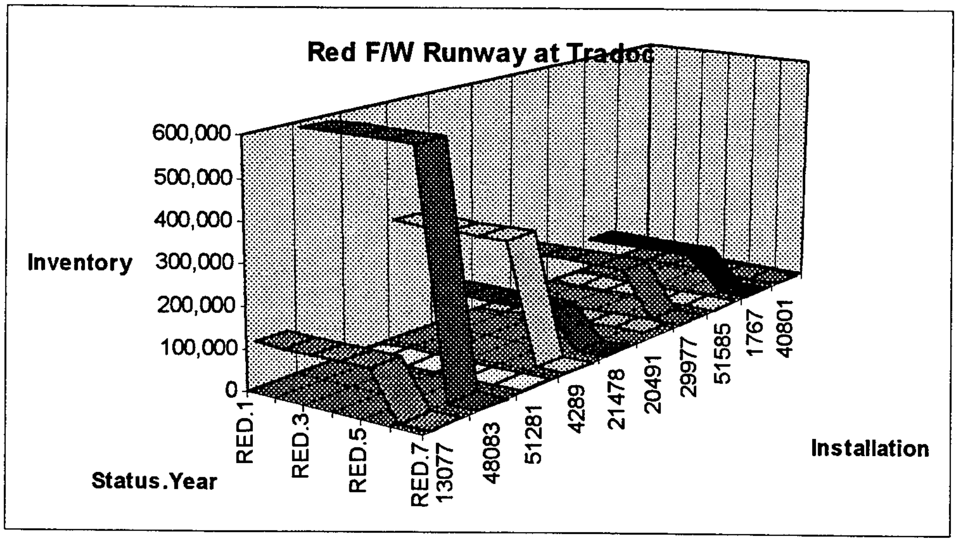

Figure 7 The projection of red inventory over the seven year time horizon. The model improved the priority 1 red inventory during year 5, one year prior to improving the priority 3 amber inventory.

The above three figures show a common result of most standard model runs. The model predominantly calculates a better gain by increasing larger amounts of inventory from amber to green before the gain from increasing smaller amounts of inventory from red to green. This outcome is the result of the improvement cost factors; the cost to raise a unit from red to green is 300 percent more than the cost to raise the same unit from amber to green.

2. Funding Sustainment of Inventory

The logical follow on question to what gain is achieved is 'How much does the gain cost?". The DST calculates the money spent on sustainment for every FCG. Table 6 is a small subset of the MACOM Military District Washington (MDW) sustainment funding. The funding is specified for each of the six years of the budget for each status

rating annotated by the column headings. GRN.1 indicates the data in this column is for green inventory during year 1.

FCGS	Installations	GRN.1	GRN.2	GRN.3	GRN.4	GRN.5	GRN.6
F85120	51062	$0	$539	$577	$617	$661	$707
F85120	24571	$0	$328	$351	$375	$401	$430
F85210	51389	$24,486	$26,200	$28,034	$29,996	$32,096	$34,342
F85210	51062	$492	$526	$9,860	$10,550	$11,288	$12,079
F85210	11564	$0	$0	$0	$0	$0	$0
F85210	24571	$0	$0	$0	$0	$0	$0
FCGS	Installations	ABR.1	ABR.2	ABR.3	ABR.4	ABR.5	ABR.6
F85120	51062	$504	$0	$0	$0	$0	$0
F85120	24571	$306	$0	$0	$0	$0	$0
F85210	51389	$0	$0	$0	$0	$0	$0
F85210	51062	$0	$0	$0	$0	$0	$7,622
F85210	11564	$86	$92	$99	$106	$113	$3,651
F85210	24571	$0	$0	$0	$0	$0	$0
FCGS	Installations	RED.1	RED.2	RED.3	RED.4	RED.5	RED.6
F85120	51062	$0	$0	$0	$0	$0	$0
F85120	24571	$0	$0	$0	$0	$0	$0
F85210	51389	$0	$0	$0	$0	$0	$0
F85210	51062	$0	$0	$0	$0	$0	$0
F85210	11564	$0	$0	$0	$0	$0	$0
F85210	24571	$456	$488	$522	$558	$597	$639

Table 6. The amount of money spent on each FCG at each installation for sustainment of inventory. The above installations are from the MACOM Military District of Washington. The above table is a subset of the total data table

Year seven is not cataloged because there is no funding allocated during year seven, rather the results of funding allocation in year six are realized as changed inventory in year seven. The data set shows this information for all inventory in all rating statuses

4. FCG Improvement Funding

Like the sustainment funding data, the model stores the money spent to improve the FCGs to green. This data set has the same two- tupple column headings. Table 7 shows a small subset of this data for the MACOM MDW.

FCGS	Installations	ABR.1	ABR.2	ABR.3	ABR.4	ABR.5	ABR.6
F85100	24571	$0	$0	$0	$0	$4,230,011	$18,881,958
F85100	51602	$0	$0	$0	$0	$0	$772,972
F85120	51389	$9,038	$9,670	$10,347	$11,071	$11,846	$12,676
F85120	51062	$372,415	$10,114	$10,821	$15,068	$16,123	$17,251
F85120	24571	$377,833	$7,838	$8,387	$9,157	$9,798	$10,484
F85210	51389	$0	$0	$0	$0	$0	$0
FCGS	Installations	RED.1	RED.2	RED.3	RED.4	RED.5	RED.6
F85100	24571	$0	$0	$0	$0	$0	$0
F85100	51602	$0	$0	$0	$0	$0	$0
F85120	51389	$0	$0	$0	$0	$0	$0
F85120	51062	$0	$0	$456,517	$0	$0	$0
F85120	24571	$0	$0	$23,964	$0	$0	$0
F85210	51389	$0	$0	$0	$0	$0	$0

Table 7. Some of the funding allocated for FCG improvement from amber to green and from red to green.

This cataloging of optimal allocation affords ACSIM the ability to give the MACOMs guidance on how to spend the RPMA dollars. This guidance has never before been given in such detail. The MACOMs usually receive guidance in the form of improving one type of FCG. For example, the Joint Chief of Staff (JCS) states the importance of the soldier's barracks, and he would like to see all the barracks improved to a high standard. A third attribute of this model is the ability to analyze the effects of such an improvement.

5. Barracks Improvement

The following example shows the effects of forcing 100 percent of the barracks inventory at USARPAC's Forts Waignwright, Richardson, Schofield Barracks, and Fort Shafter to a green status by the beginning of year seven. Figure 8 shows the green inventory of barracks at the four installations after a standard model run without

mandating the 100 percent green status, while Figure 9 shows the same inventory after 100 percent of the barracks inventory has been forced to green status by year seven.

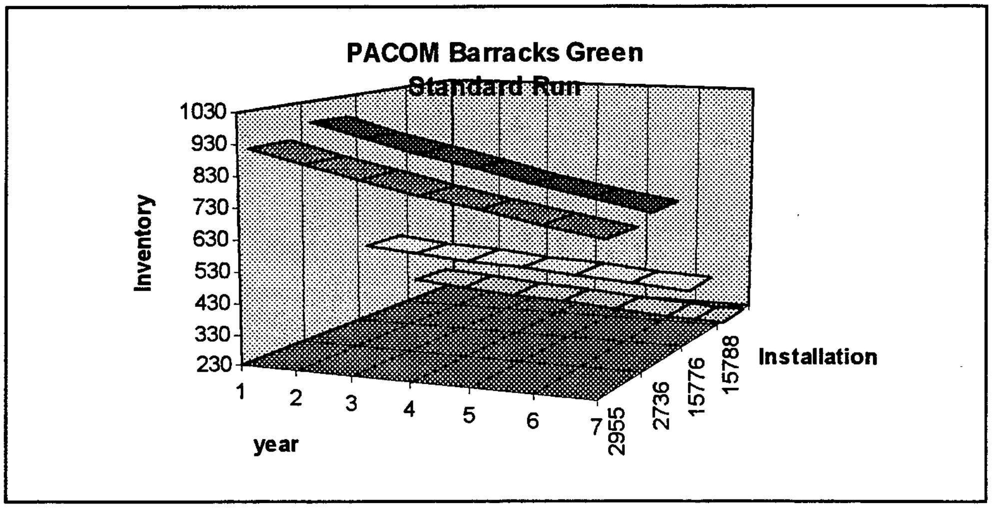

Figure 8. The depreciation of barracks space in a green status. All four installations prioritize barracks inventory as 1, but the model can not maintain all the priority 1 inventory with the proposed USARPAC RPMA budget.

The model obtains these forced results by one of two means. First, the model could calculate the amount of over budget money required to execute this additional increase in inventory. Second, the model could calculate the improvement in barracks inventory by decreasing the amount of improvement or sustainment of another inventory. This excursion maintains the penalty and end state of over budget at the standard 0.1 and 0 respectively, ensuring the model does not go over budget.

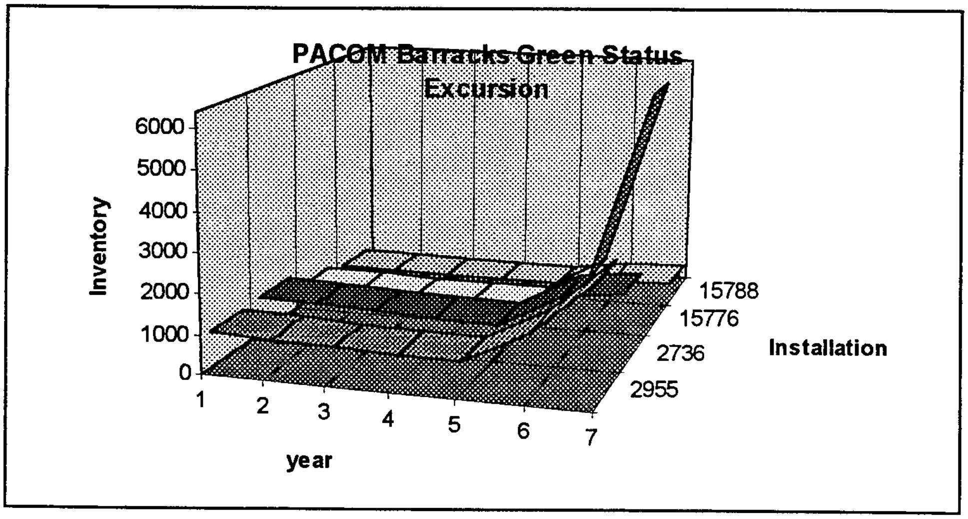

Figure 9. The status of green barracks inventory after the inventory is fixed at 100 percent green at year 7. Not shown is the significant effect this mandate has on other FCGs. 53 FCGs show a greater than 20% loss in green inventory.

The total cost to improve the current barracks conditions to a green status at these four installations is $163,050,642 in 1996 dollars. This dollar amount equates to over 14 percent of the total six year RPMA budget for USARPAC, or between 80 to 100.1 percent of the annual USARPAC RPMA allocations. Assuming that Congress will not allocate the additional moneys for the JCS's desired improvement, ACSIM can illustrate a significant loss in other FCG statuses caused by improving the status of barracks. Balancing for the improved barracks inventory, the model must significantly decrease the amount of inventory previously raised to a green status across hundreds of other FCGs. This decrease effected all eight USARPAC installations. 53 of these FCGs showed a greater than 20 percent loss in green inventory at year seven. 23 of the 53 showed a 90 percent decrease in green inventory at year seven, and 16 showed a decrease of 100 percent.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The Decision Support Tool modeled in this thesis creates an optimal funding allocation and an inventory status projector ACSIM needs to efficiently manage and defend its budget. The model uses data verified and accepted by ACSIM creating a robust and powerful model to quantify the complex budgeting problem.

In general, ACSIM can implement this model into its budget planning now. As the data from the ISR and other sources improves from refinement, the model can produce very accurate projections of inventory status and the ability to define allocation methodologies to achieve the projected status.

B. RECOMMENDATIONS

The model's methodology is powerful, understandable and verifiable. However, some data could be improved. The cost factors developed by CEAC are derived from all the installations in the continental United States, then aggregated into one Army cost factor. If these factor were obtained at the installation or regional level, the model could easily accommodate the greater detail.

The percentage of unsustained inventory which depreciates to the next lower status, the percloss parameter, can be refined using the FDM. This more accurate data will greatly increase the accuracy of the status projections.

The minimum percentage of sustained inventory should be refined. The current standard rate of 3% of the total sustainment cost is clearly too general. ACSIM has already done work in this area, and the improved $minesen_{f,i,t}$ data is necessary for more realistic results.

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